either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage—when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entailed a monetary loss of several millions sterling in the three kingdoms—that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds,—that there is a constant annual expenditure of enormous amounts for removing *débris* from navigable channels, the accumulation of which could be mainly, if not entirely prevented,—that the supply of food to our rapidly growing population, dependent, as it is at present, upon sources outside the country, would be enormously increased by an adequate protection of the fisheries,—that the same supply would be further greatly increased by the extra production of the land when increased facilities for drainage are afforded,—that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature, I believe it will be allowed that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

I do not wish it to be understood that in suggesting the collection of additional data relating to the phenomena of rivers, I am advocating delay in dealing with the existing state of things until the facts have all been ascertained. On the contrary, I believe that the first step ought to be the establishment of a distinct Water Department, which should at once address itself to the remedying of the evils which are found to be most pressing. The time has long since arrived when the present neglected state of many of our most important streams should be dealt with, and that this was also the conviction of Parliament and of the government is evident, from the appointment of such an influential Committee as that presided over by the Duke of Richmond last session.

A new department should be created—one not only endowed with powers analagous to those of the Local Government Board, but charged with the duty of collecting and digesting for use all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river, basin, or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the government who can be appealed to in Parliament.

The department should have entire charge of, and control over, all estuaries and navigable channels, both because these are used by foreign vessels, and therefore the responsibilities attaching to their preservation are international, and because they must be protected from hostile attack, and on these accounts are essentially imperial property. For the same reason the cost of amending and maintaining them should be defrayed out of the imperial exchequer.

As regards the regulation of the remainder of the watershed area, the conclusions arrived at in the Report of the Duke of Richmond's Select Committee seem to me entirely satisfactory. I cannot do better than give a few extracts from that Report. The Committee say—"That in order to secure uniformity and completeness of action each catchment area should, as a general rule, be placed under a single body of conservators, who should be responsible for maintaining the river from its source to its outfall in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to district committees acting under the general direction of the conservators, but near the point of junction with the principal stream they should be under the direct management of the conservators of the main channel, who should be a representative body constituted of residents and owners of property within the whole area of the watershed. The Committee go on to say that "means should be taken to ensure the appointment of a conservancy board for each watershed area," but that application should first be made by persons interested in the district, and that then the departmental authorities should send inspectors to make local inquiries and to report upon the "necessities and capacities of the district, and suggest the area and proportions of taxation."

With regard to what is probably the most important point of all, the finding of the money necessary to carry out these recommendations, the Committee advocate the introduction of a new principle of taxation, the soundness of which cannot be questioned. Instead of the principle first introduced by the statute of Henry the Eighth, and observed ever since, of levying taxes in proportion to the direct benefit conferred, the Committee propose that the rates should be distributed over the whole area of a watershed, including not only the lands, but the towns and houses and all other property situate within that area. This is in fact no more than a general application of the law of highways, which in the time of the Romans, according to Justinian, applied equally to waterways. It is perfectly just that every acre, the drainage of which contributes to the flow of the streams and rivers of every watershed area, should, in some proportion or other, contribute also to the cost of maintaining the channels of those streams and rivers in an efficient state. The incidence of the taxation must of course, as has been pointed out, be determined by the circumstances of each particular case, but there is no doubt that the conclusion of the Duke of Richmond's Committee, that "the taxation should be levied on the basis of rateable value," is the only sound, and at the same time practical, way of dealing with this difficulty.

The word "taxation" is not, I fear, generally connected with any idea of profit to the individual taxpayer. But in this case, as I hope in the course of this address I have made clear, the prevention of large present losses, and the advantages gained by an improved system, will give not only a fair but an ample return on the capital expended.

It is my firm belief that an intelligent management of watershed areas would be compatible with an absolute profit to every interest affected; that we have here no question of give and take, but that in this, as in every other case, the laws of nature, under proper and scientific regulation, can be made subservient to the needs of the highest civilisation.

THE PHONOGRAPH AND VOWEL SOUNDS [1]

III.

We now pass to the general conclusions which may be drawn from our experiments. In the first place it seems clear that vowels do not depend on pitch alone or on the simple grouping of partial tones independently of absolute pitch. Before the constituents of a vowel can be assigned, the pitch of the prime must be named. But on the other hand the pitch of the most prominent partial of the group is not alone sufficient to allow us to name the vowel in which it appears; to do this we also require to be told the relation of the constituent partials to one another.

The sound *ū* consists mainly of one tone generally lying in the region above *a*.

The sound *ō* requires at least two partials; when there are only two important ones these lie in the region between *g* and *f*″, a region covering nearly two octaves. Indeed the upper limit may extend above *f*″ with a tenor or woman's voice. Other partials than the prime are reinforced by the mouth-cavity over all this region. This great range is obviously a distinguishing mark of *ō* as compared with *ū*, perhaps *the* distinguishing mark; for when *ū* and *ō* are sung at various pitches, the most prominent partial, first of one letter and then of the other, is highest, and the most prominent partial of both sounds may lie on *b*′♭, the characteristic tone of *ō*. An *ū* sung on *b*♭ may even have the tone *b*′♭ more strongly present in it than an *ō* of the same pitch. When *ū* was sung by voice 1 on *b*♭ the prominent partial was the second; when *ō* was sung at the same pitch by the same voice, the second partial was still the most prominent. Thus for voice 1 the chief distinction between *ū* and *ō* on this note lay not in the pitch of strongest reinforcement, but in the fact that the prime was larger for *ō* than for *ū*. When voice 5 sang *ū* on *b*♭ the prominent partial was the prime; when it sang *ō* the prominent partial was the second, the prime being also strong. Thus, for voice 1, the distinction lay in the fact that the prime was much smaller for *ō* than for *ū*. It is obvious here that the ear cannot have been guided by the absolute pitch of the reinforcement to the distinction between *ō* and *ū*. At this pitch the distinction lies in the fact that *ō* contains two strong partials (the prime and second), whereas *ū* contains only one (the prime *or* the second). The argument is not weakened by saying that the *ū* of one voice was not the same as the *ū* of the other. Identically the same it cannot have been; nevertheless, on higher or lower notes the two voices agreed as to the composition of *ū*, and generically the vowels were certainly the

[1] Continued from p. 397.

same. There remains the fact that speakers and hearers were unconscious of any generic change in the vowel ū when the pitch of the strongly-reinforced partial changed by a whole octave.

On the other hand, it is equally clear the voice, in singing a given vowel at various pitches, does not simply produce a certain constant group of relative partial tones. Possibly, indeed, the ear might recognise a single tone, especially if very feebly accompanied by higher harmonics, as a kind of ū outside the region within which the human voice forms ū in that way. Thus Helmholtz, in his *Tonempfindungen*, says that the single tone B♭, when sounded alone, gave a very dull ū, much duller than could be produced by the voice. This tone is an octave below the place where voice 1 ceased to make ū by reinforcing the prime. Quite similarly it is conceivable that the group consisting of a prime and its octave might be recognised as ō even when produced below the limits within which the human voice does produce this simple harmony in singing ō. Our own impression as to the result of running the phonograph slower when it is speaking than when it is spoken to, supports this view, but we do not desire to base any inference on that. Certainly the low ō produced in this manner is not the human ō.

Moreover, we find a very decided resemblance in the relative constituents of ō at a low pitch and a° or ā at higher pitches. ō in the neighbourhood of B♭, and ā in the neighbourhood of *f* and *g*, are pretty similarly constituted. Our experiments on a° and ā are not sufficiently extended to allow any very general conclusions to be drawn, but they are sufficient to show that between certain vowels the main distinction must lie in the absolute pitch of the reinforced group of partial tones.

We are thus brought back to our original statement that in distinguishing vowels the ear is aided by two factors, one depending on the harmony or group of partials, and the other on the absolute pitch of the constituents. It seems not a little singular that the ear should attribute a distinct unity to sounds so dissimilar in their relative and absolute composition as those represented by the curves of Fig. 1.

We are forced to the conclusion already adopted by Helmholtz and Donders that the ear recognises the kind of cavity by which the reinforcement is produced; that although the sounds which issue differ so much that we fail when they are graphically represented and mathematically analysed to grasp any one prominent common feature, nevertheless by long practice the ear is able to distinguish between the different sorts of cavities which are formed in pronouncing given vowels. Something of the same kind may be observed with other sources of sound than the human voice; the resonating cavities of various musical instruments aid greatly in allowing each particular species to be recognised at once, though their effect must be widely different at different parts of the scale. It is, moreover, no mere inference that we recognise the cavity. Prof. Crum Brown's gutta percha bottle, described before, proves that we do, and that it is a group of tones reinforced by a particular kind of cavity that we call a particular vowel. But we have to consider what light the experiments throw on the kinds of cavity that are required for certain vowels. The cavities are clearly distinguished in virtue of two distinct properties: first, the pitch of their maximum resonance or strongest proper tone, and second the range of reinforcement which they are capable of producing. This latter property has, we believe, been hitherto much neglected.

Prof. Crum Brown's bottle proves that a *constant* cavity is capable of producing the constant vowel ō over a large range of pitch. On the other hand our experiments with various human voices singing ō appear to exhibit a *tuning* of the cavity by which new partials are sometimes introduced somewhat abruptly; and for the sound ū it seems certain that the cavity is tuned, that is to say, that the pitch of its proper tone is not the same when the vowel is sung on different pitches. The appreciably strong *fourth* partial in all the duplex ū's of Table VI. may here be noticed as favouring the view that in each of these examples the oral cavity had been adjusted so as to be in unison with the second partial. We may describe the ū cavity as an adjustable cavity with a very limited range of resonance, whose effect is to reinforce strongly only one partial lying above *a*. It is possible that this cavity may keep itself constant throughout the very limited range of pitch employed in ordinary speech, but when the range is increased as in singing, a certain tuning seems indispensable.

If we assume that the ō cavity is absolutely constant, we must describe it as a cavity capable of reinforcing more or less strongly tones lying anywhere between *g* and *f''*. This cavity

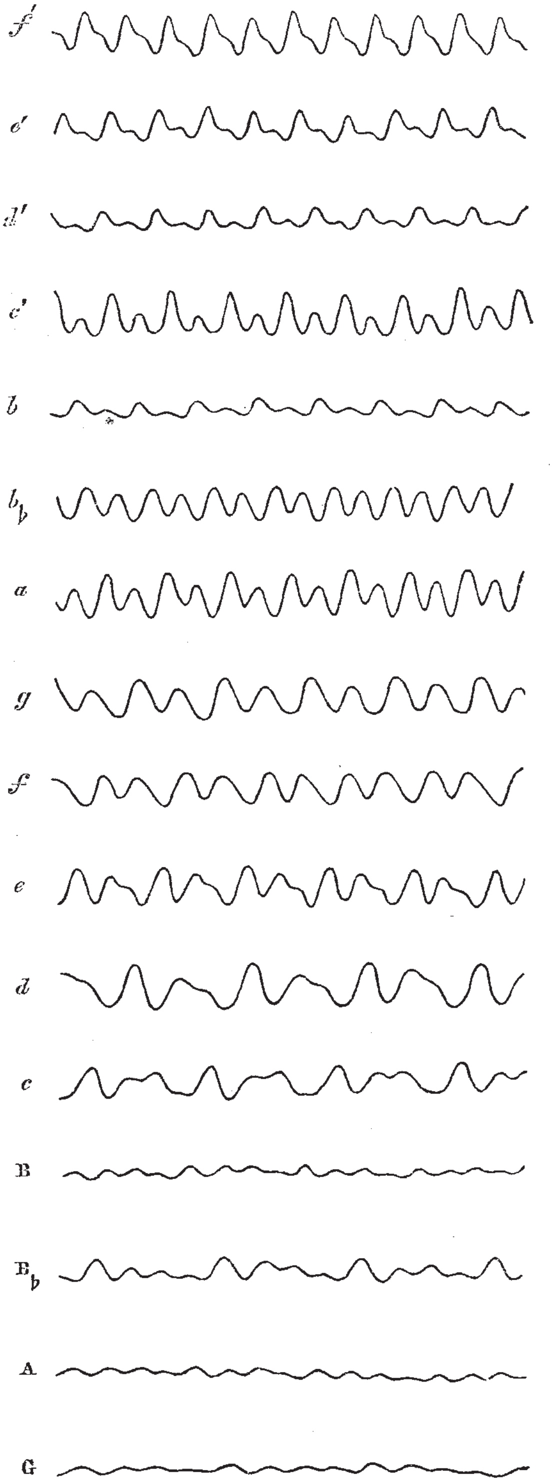

Fig. 1.[1]—*Wave-forms of ō Sung by the same Voice at Various Pitches.*

[1] We reproduce this week the figure which accompanied Profs. Jenkin and Ewing's first paper, on "The Wave-Form of Ō," p. 342. It shows the delicate forms of the curves with greater exactness, and will enable the reader to understand more clearly the value of the conclusions come to by the authors.—Ed.

has, in the case of all the human voices investigated, one strong proper tone in $b'\flat$, but as the cavity which produced the artificial $\bar{o}$'s did not possess this characteristic, and it was possessed by different voices in very different degrees, it should perhaps be regarded as an accident of the human voice rather than as essential to the production of the vowel. It is difficult, however, on the constant cavity hypothesis, to see how the third partial of an $\bar{o}$ sung on or near a should not be stronger than it is. We are disposed to regard it as more probable that the $\bar{o}$ cavity also is tuned. We do not mean by this that it has a proper tone always in unison with one of the partials of the note sung, but only that there is a tendency to accommodate the pitch of the cavity so that it shall reinforce some partial more strongly than might have been the case without this tuning. On this view the range of reinforcement of each $\bar{o}$ cavity need not extend over much more than an octave, nor the range of adjustment over so much as six semitones. The upper reinforcement would lie round about $b'\flat$, on which note the greatest reinforcement can be given. Another way of putting the same conclusion would be to say that the generic character of the human $\bar{o}$ was given by the fact that the range of reinforcement of any $\bar{o}$ cavity extends over rather more than an octave, with an upper and strongest proper tone never far from $b'\flat$, but sometimes deviating slightly from that pitch on account of the voice choosing its cavity so as to bring a strong proper tone more closely into unison with one of the upper harmonics of the note sung.

We should describe the $\bar{a}$ cavity as differing from that for $\bar{o}$ chiefly in having a higher general pitch of resonance, and perhaps, also, a wider range.

It is evident that Willis and Wheatstone were right in considering that the vowel quality was given by a particular resonator, and that the pitch of maximum resonance of the resonator was an important element in determining the vowel character of the sounds produced. Willis's vowels were not thoroughly recognisable because the form and material of his resonator were not adapted to include the second element of range of reinforcement.

Further, our experiments agree with the observation of Donders that there is a pitch of maximum resonance in human mouth cavities for the vowel $\bar{o}$, although, as we have said above, we are disposed to consider the $\bar{o}$ cavity as not quite constant. We fail to distinguish any such characteristic tone in the case of $\bar{u}$, and we observe that it is fixed by Helmholtz only with considerable diffidence.

Our experiments entirely confirm Helmholtz's statement that vowel sounds are made up of harmonic partial tones, and the groups of partials, so far as he gives them, for the vowels we have investigated, agree fairly well with our results. Since these experiments were brought to a close our attention has been directed to a paper by Felix Auerbach (*Pogg. Ann. Ergänzung*, viii. 2), containing an account of experiments on vowel sounds made by him in Prof. Helmholtz's laboratory. By the aid of resonators applied to the ear he made numerical estimates of the strength of the several partial tones when vowels were sung on various notes. He was led, as we have been, to the conclusion that the relative partials were an important factor in the result as well as the absolute pitch, but we cannot say that our numbers agree with his estimates or support the deductions which he has drawn from them.

FLEEMING JENKIN
J. A. EWING

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

THE directors of the Polytechnic are about to make an important alteration in the science department of this institution. It is intended to separate the laboratory from the rest of the institution, and to establish a high-class school of practical science in all its branches. Dr. Edward B. Aveling has been appointed to the charge of this laboratory, and intends forthwith to establish classes for practical instruction in all the science subjects required for the university, government, and other examinations.

THE first series of 500 select public teachers in France arrived in Paris on August 15 to visit the Exhibition, at the expense of the government. They are accompanied by 1,000 teachers of the same districts travelling at their own expense, but conveyed at half price by the various railway companies, and boarded in several Paris colleges. They were received at the Sorbonne, in the large hall, by M. Casimir-Périer, the Sub-Minister of Public Instruction, and lectured by M. Levasseur on the teaching of geography. They will be lectured on the teaching of French, of history, and on the organisation of lectures and public libraries. They will leave on Friday, and be succeeded by another set of teachers.

M. BARDOUX has issued a circular intimating that a special financial department has been created for facilitating the building of school-houses in the several French communes. A credit of 60,000,000 francs has been voted by the Chambers, and will be divided amongst the several municipalities that desire to improve or rebuild their public schools, on the condition that each should expend a sum of at least double that taken from the public exchequer.

PROF. A. WOLTMANN, of Prague, has accepted a call to the directorship of the Archæological Institute at Strasburg.

THE first experiment of an educational turn for children, about which we spoke some months ago, has given such good results that a new society is in process of formation at St. Petersburg for a similar purpose. Several eminent teachers of the Russian capital have offered their services to the society, which will yearly send out companies of children on educational travel, as well as parties of young ladies and young men who have finished their studies in secondary schools, or are following the courses of high schools.

SOCIETIES AND ACADEMIES

PARIS

Academy of Sciences, August 12.—M. Fizeau, president.—On the composition of the milk of the cow-tree (*Brosmium galactodendron*), by M. Boussingault. He finds that while the general constitution of the juice of the cow-tree approaches that of milk, the proportions of the various substances are very different.—Observation on the discovery announced by Mr. L. Smith of a new earth belonging to the cerium group, by M. C. Marignac. He does not see any reason for distinguishing the supposed new earth from terbene.—Studies on the placenta of the Aï (*Bradypus tridactylus*, Lin.); the place which that animal should occupy in the series of mammals, by M. N. Joly.—On the fundamental co-variants of a cubo-biquadratic binary system, by Prof. Sylvester.—New process for the analysis of milk, yielding rapidly butter, lactose, and caseine, in one and the same specimen, by M. A. Adam.—M. J. Vinot sent to the Academy a letter addressed to him by Leverrier in September, 1876, in which the late astronomer inferred, from various observations, that there are two intra-Mercurial planets.—On the functions of leaves; function of the stomata in the exhalation and inhalation of aqueous vapours by leaves, by M. Merget.—On the delay of the pulse in intra-thoracic aneurisms and in aortic insufficiency, by M. Fr. Franck.—Chemical researches on the division of cyclamine into glucose and mannite, by M. S. de Luca.—On parasitic isopods of the genus Entoniscus, by M. Alf. Giard.—On the changes of colour of *Nika edulis*, by M. S. Jourdain.—Importance of the partition of vegetable cells in the phenomena of nutrition, by M. Max. Cornu.—On the part of stipules in inflorescence and in the flower, by M. D. Clos.—On the fall of avalanches, by M. Ch. Dufour.

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